Seasonal Dynamics in Plankton Abundance and Diversity of a Freshwater Body in Etche, Nigeria

Dike Henry Ogbuagu[1] & Adedolapo Abeke Ayoade[2]

[1] Department of Environmental Technology, Federal University of Technology, Owerri, Nigeria

[2] Department of Zoology, University of Ibadan, Ibadan, Nigeria

Correspondence: Dike Henry Ogbuagu, Department of Environmental Technology, Federal University of Technology, PMB 1526, Owerri, Nigeria. Tel: 234-703-885-0065. E-mail: henrydike2002@yahoo.com

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Abstract

Fluctuation in plankton abundance and diversity of the Imo River in Etche, a Niger Delta region of Nigeria was investigated. Plankton samples were collected with 55 micro meter mesh size plankton net at 7 sampling locations once monthly between March 2007 and February 2009. Samples were preserved with 4% formalin solution in labeled plastic containers in the field. In the laboratory, 1ml of the plankton subsample was withdrawn with a wide-mouthed pipette from field samples and placed on a Sedge-wick rafter-counting chamber for species identification and counts with standard keys through direct microscopy. The studentized t-test of significance was used to partition numerical abundances of plankton biotypes seasonally. Phytoplankton comprised 43 genera and a mean density of 1859 cells/ml. The dominant phytoplankton was the Bacillariophyceae (53.25%), followed in order by Cyanophyceae (21.25%), Chlorophyceae (10.33%), Chrysophyceae (4.84%), Pyrrophyceae (4.57%), Xanthophyceae (3.39%) and Euglenophyceae (2.42%). Zooplankton was made up of 7 taxa and a mean density of 433 organisms/ml. The order of dominance was the Cladocera (25.87%), Copepoda (20.55%), Protozoans (19.17%), Rotifera (18.71%), fish eggs and larvae (9.24%), Crab larvae (4.62%), and Beetle larvae (0.69%). Phytoplankton species showed oscillating as well as stable seasonal patterns of occurrence. Higher Margalef's diversities were recorded in the dry (3.655; 57% and 1.273; 61%) than wet season (2.732; 43% and 0.810; 39%) for phytoplankton and zooplankton biotypes, respectively. Phyto- and zoo-plankton taxa each showed significant numerical differences between the 2007/2008 and 2008/2009 sampling periods [$F_{(14.39)} > F_{crit(4.30)}$ and $F_{(29.08)} > F_{crit(4.23)}$, respectively] at $P<0.05$. The observed seasonal peaking in abundance could be attributed to periods of concentrations of nutrients and stability in growth factors of plankton biotypes.

Keywords: Etche Local Government Area, phytoplankton, zooplankton, seasonal variation, plankton biotypes, plankton diversity

1. Introduction

The effects of environmental factors on plankton dynamics has been investigated by several authors (Kagalou et al., 1999; Hassan et al., 2004; Susanne et al., 2005; Nowrouzi & Valavi, 2011; Ogbuagu et al., 2011). The influence of these factors on the seasonal abundance and diversity of plankton biotypes varies significantly, with physical factors like temperature and light intensity being the most important and chemical factors like dissolved oxygen, pH, salinity, hardness, electrical conductivity and nutrient level being of lesser importance (Reynolds, 1984).

Albeit, since our knowledge of the dynamics of plankton populations in relation to these factors can sometimes be unpredictable (Mur, 1997; Pongswat et al., 2000) and data on the plankton biotypes of the Imo River are lacking, this study attempted the determination of seasonal fluctuations in phytoplankton and zooplankton distributions, abundance and diversity in the middle reaches of the river.

2. Materials and Methods

2.1 Study Area

The study was conducted in the middle course of the Imo River which covers Etche Local Government Area (LGA) in Rivers State, Nigeria; between longitude 06˚ 05' and 07˚ 14'E and latitude 05˚ 08' and 04˚ 45' N

(Figure 1). Here the river experiences flooding during the peak of the wet season. The inhabitants practice subsistent agriculture and the climate is typical of the tropical rainforest zone; with annual rainfall between 160-236 cm in about 300 rain days, especially during March-November. Temperature ranges are between 24 and 38 ºC, and the predominant wind direction is Northerly winds, with significant influences from the Southerly winds. Humidities of up to 90% are usually recorded during the wet season while values as low as 40% could be recorded at the peak of the dry season (SPDC, 1998). In the neighborhoods of majority of the sampling locations are ongoing oil exploitation activities by the Shell Petroleum Development Company of Nigeria (SPDC), whose activities dates back to 1958 when crude oil was first discovered in the area.

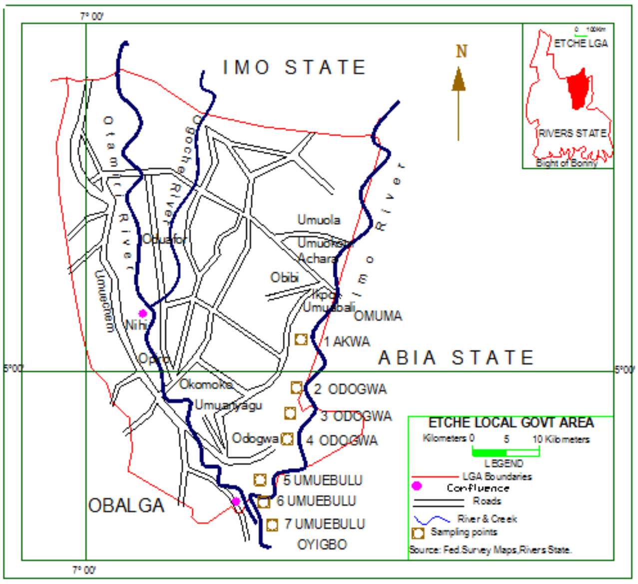

Figure1. Map of Etche LGA showing the sampling locations along Imo River

2.2 Sampling Locations

The study was conducted once monthly for 24 months between March 2007 and February 2009 at 7 sampling locations along the river course. Sampling location 1 was sited upstream at Akwa community. Sampling locations 2, 3, and 4 were sited about 1 km apart at Odogwa community, with location 2 situated about 2 km from 1. Locations 5, 6, and 7 were also situated about 1 km apart at Umuebulu community; with location 5 situated about 3 km from 4. Odogwa and Umuebulu communities house oil and gas facilities belonging to the SPDC. In-stream sand mining was ongoing at all the sampling locations, with less severity in location 1.

2.3 Field Sampling

Using a locally constructed boat for transportation, plankton net of mesh size 55µm was hauled horizontally along the river course for 5 minutes at each sampling location according to the methods of Grant (2002) and Anene (2003). The resultant concentrated plankton samples were later transferred to plastic containers, fixed and preserved in 4 % formalin solution according to the method of Boney (1983) and Anene (2003) in the field.

2.4 Laboratory Analysis

Samples were homogenized by inverting the containers few times. With a wide-mouthed pipette, 1ml of the plankton subsample was withdrawn from the field samples, placed on a Sedge-wick rafter-counting chamber and observed by direct microscopy. Keys provided by Whitford and Schumacher (1973), Needham and Needham (1974), Cole (1978), Maosen (1978), Jeje and Fernando (1986; 1991), Egborge (1994), and APHA (1998) were used for species identifications. Counts were made in triplicates and their averages taken and expressed as either cells/ml (phytoplankton) or organisms/ml (zooplankton) of water.

2.5 Statistical Analyses

Seasonal partitioning of plankton biotype abundances was done with the studentized t-test of significance at $P<0.05$. Species diversity was determined with the Margalef's index (I) (Margalef, 1961).

3. Results

3.1 Plankton Composition and Abundance

A total of 2292 plankton cells or organisms/ml of water was counted in the river during the study period. Out of this, 1859 cells/ml were phytoplankton while 433 organisms/ml were zooplankton species. Seven taxa each were recorded for the phytoplankton and zooplankton (Appendix 1).

3.2 Seasonal Variation in Plankton Abundance

Though plankton abundance peaked in February 2009 (dry season month) and was least in October and November 2007 (wet season months), the cumulative trend was that of higher abundance in the wet than dry season months. For the phytoplankton, a total of 1179 cells/ml (63.39%) were identified during the wet season, while 681 cells/ml (36.61%) were identified during the dry season. On the other hand for the zooplankton, 282 and 151 organisms/ml (65.13% & 34.87%) were identified in the wet and dry seasons, respectively.

Through the seasons, the bacillariophycean phytoplankton accounted for the highest abundances of 627 and 363cells/ml in the wet and dry seasons, respectively, while the euglenophyceans & xanthophyceans accounted for the least abundances of 20 and 22 cells/ml each in the wet and dry seasons, respectively. The order of abundance of the phytoplankton families during the wet season was Bacillariophyceae>Cyanophyceae> Chlorophyceae> Pyrrophyceae> Chrysophyceae> Xanthophyceae> Euglenophyceae. During the dry season, the order was Bacillariophyceae>Cyanophyceae>Chlorophyceae> Chrysophyceae> Euglenophyceae> Pyrrophyceae> Xanthophyceae.

The order of abundance of the zooplankton classes identified during the wet seasons was Cladocera> Copepoda> Protozoa> Rotifera> fish eggs/larvae> crab larvae> beetle larvae while in the dry season it was Cladocera> Copepoda> Rotifer> Protozoa> fish eggs/larvae> crab larvae> beetle larvae.

Numerical abundances of the diatoms, blue-green algae, green algae and chrysophyceans peaked in February (Figure 2 and Figure 3), while the euglenophyceans, pyrrophyceans and xanthophyceans peaked in February and March (Figure 4) of the study period. However, abundances of the cladocerans, copepods (Figure 5) and rotifers and protozoans (Figure 7) peaked in February, while those of the crab larvae peaked in September 2007 (Figure 6), fish eggs and larvae peaked in September and October (Figure 6), and beetle larvae were only present in September (Figure 7) of the study period.

Mean diatom counts were lower in the wet (38.17 ± 3.31 cells/ml) than dry season (60.50 ± 10.24 cells/ml) months of the sampling period (Table 1). The studentized sig. t-value of 0.136 indicates that there was no significant difference in bacillariophycean abundances between the wet and dry seasons, while the sig. r-value of 0.180 also indicate no significant seasonal correlation at $P<0.05$.

Mean cyanophycean counts were also lower in the wet (15.83 ± 1.89 cells/ml) than dry season months (24.33 ± 5.00 cells/ml); with neither statistically significant seasonal difference (sig. t = 0.08), nor significant correlation (sig. r = 0.251) (Table 1).

The green algae also recorded higher mean counts in the dry (11.83 ± 2.77 cell/ml) than wet season months (6.00 ± 0.93 cells/ml); with neither significantly different seasonal abundances (sig. t = 0.120), nor significant seasonal correlation (sig. r = 0.676) (Table 1).

However, the other phytoplankton biotypes identified (Chrysophyceae, Euglenophyceae, Pyrrophyceae and Xanthophyceae) did not also reveal significant seasonal differences, as well as correlations (Table 1).

Of the zooplankton, cladocerans recorded more counts in the dry (7.33 ± 1.41 organisms/ml) than wet season (4.17 ± 0.48 organisms/ml), and also showed significant seasonal correlation (sig. r = 0.012), but no significant seasonal difference (sig. t = 0.148) at $P<0.05$. The absence of beetle larvae in dry season months did not enable the computation of seasonal correlation and differences. However, the other zooplankton biotypes (copepods, crab larvae, fish eggs and larvae, rotifers and protozoans) neither showed significant seasonal correlations, nor differences at $P<0.05$ during the study period.

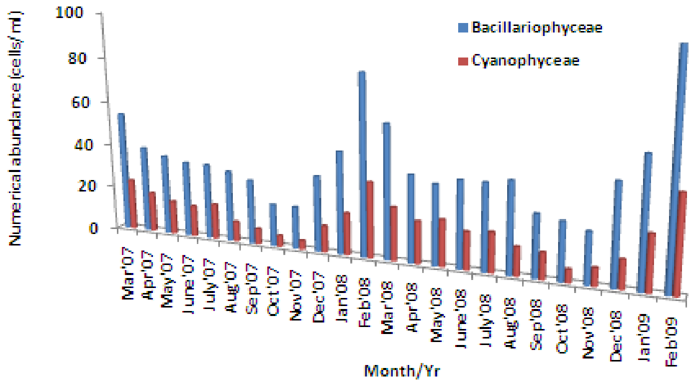

Figure 2. Monthly numerical abundance of Bacillariophyceae and Cyanophyceae taxa of lmo River in Etche LGA

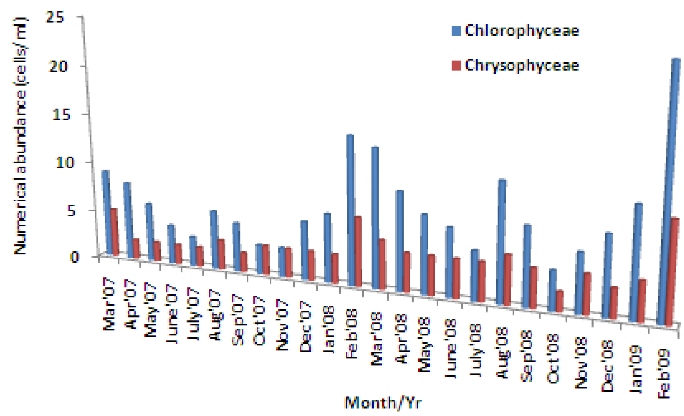

Figure 3. Monthly numerical abundance of Chlorophyceae and Chrysophyceae taxa of Imo River in Etche LGA

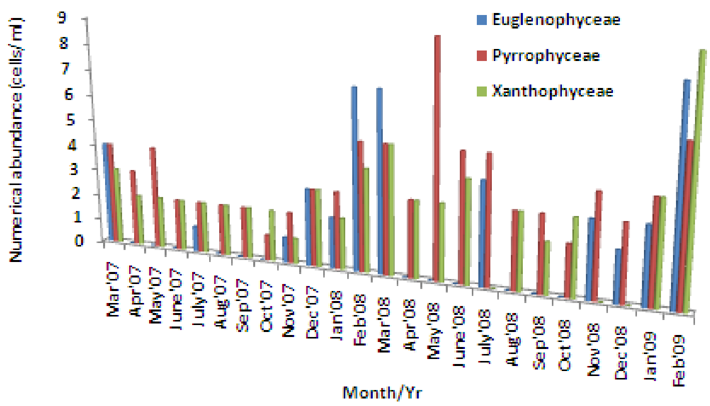

Figure 4. Monthly numerical abundance of Euglenophyceae, Pyrrophyceae and Xanthophyceae taxa of Imo River in Etche LGA

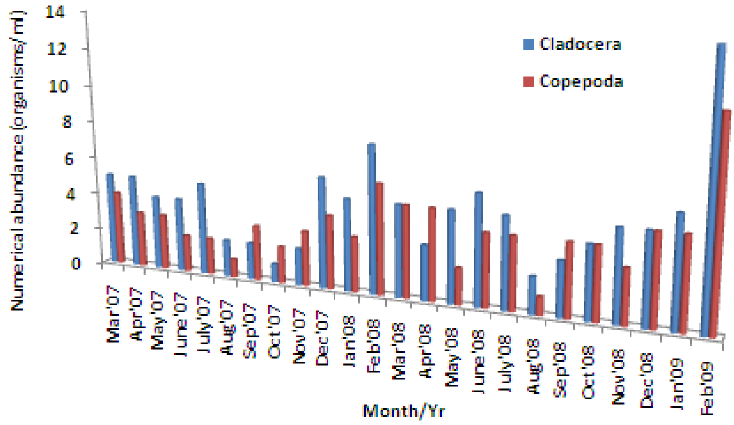

Figure 5. Monthly numerical abundance of Cladocera and Copepoda taxa of Imo River in Etche LGA

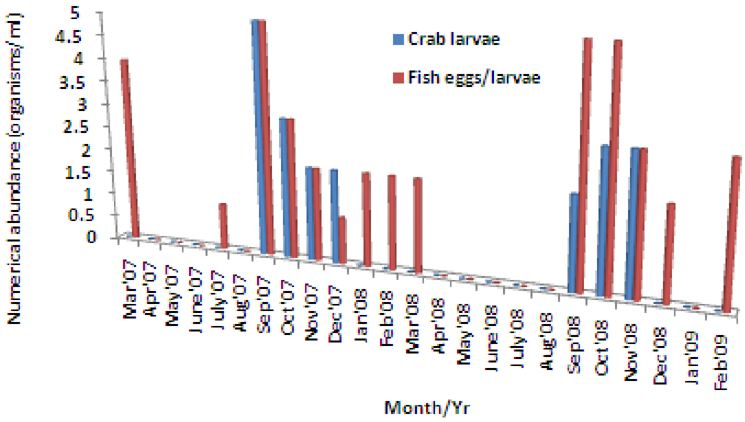

Figure 6. Monthly numerical abundance of crab larvae and fish eggs/larvae of Imo River in Etche LGA

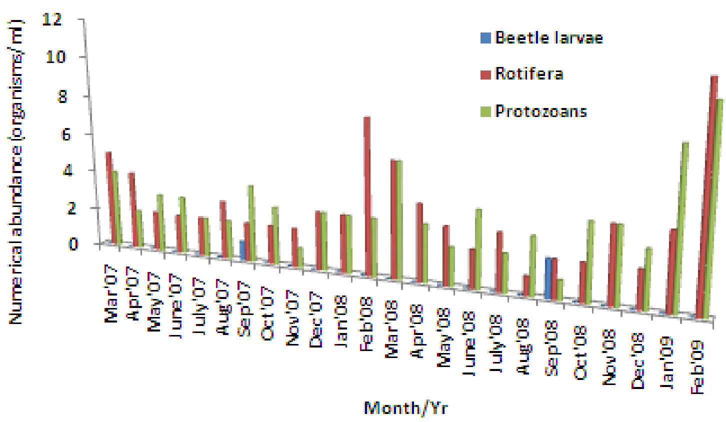

Figure 7. Monthly numerical abundance of beetle larvae, Rotifera and Protozoan taxa of Imo River in Etche LGA

However, both phytoplankton and zooplankton taxa showed significant numerical differences between the 2007/2008 and 2008/2009 sampling periods [$F_{(14.39)} > F_{crit(4.30)}$ and $F_{(29.08)} > F_{crit(4.23)}$, respectively] at $P<0.05$.

3.3 Seasonality and Diversity Index

Higher Margalef's diversities were also recorded in the dry than wet season months of the study period. In the wet season, mean phytoplankton diversity was 2.732 (43%) and in the dry season, it was 3.655 (57%) (Figure 8). The zooplankton biotypes exhibited lower mean Margalef's diversities of 0.810 (39%) and 1.273 (61%) in the wet and dry seasons, respectively (Figure 9).

Table 1. Seasonal variation in plankton densities of Imo River in ELGA using the studentized t-test of significance ($P<0.05$)

Plankton taxa	Season	Mean	SE	Correlation (r)	Sig. r -value	t	Sig. t-value
Bacillariophyceae	Wet	38.17	3.31	-0.630	0.180	-1.774	0.136
	Dry	60.50	10.24				
Cyanophyceae	Wet	15.83	1.89	-0.758	0.081	-1.297	0.251
	Dry	24.33	5.00				
Chlorophyceae	Wet	6.00	0.93	-0.219	0.676	-1.874	0.120
	Dry	11.83	2.77				
Chrysophyceae	Wet	2.67	0.49	-0.057	0.915	-1.784	0.135
	Dry	5.00	1.18				
Euglenophyceae	Wet	0.83	0.65	-0.276	0.597	-2.370	0.064
	Dry	4.17	1.08				
Pyrrophyceae	Wet	2.83	0.40	-0.161	0.761	-1.659	0.158
	Dry	4.00	0.52				
Xanthophyceae	Wet	2.17	0.17	-0.108	0.838	-1.192	0.287
	Dry	3.67	1.23				
Cladocera	Wet	4.17	0.48	-0.910	0.012	-1.710	0.148
	Dry	7.33	1.41				
Copepoda	Wet	2.50	0.43	-0.748	0.087	-2.122	0.087
	Dry	5.67	1.15				
Other Crustaceans	Wet	1.00	0.01	-0.524	0.286	-1.000	0.363
	Dry	0.33	0.01				
Fish eggs & larvae	Wet	0.83	0.65	-0.223	0.671	-0.881	0.419
	Dry	1.67	0.42				
Beetle larvae	Wet	0.17	0.00	-	-	-	-
	Dry	0.00	0.00				
Rotifera	Wet	3.00	0.52	-0.223	0.671	-1.320	0.244
	Dry	5.17	1.45				
Protozoa	Wet	2.67	0.33	-0.620	0.189	-1.535	0.185
	Dry	5.00	1.29				

SE = standard error of mean

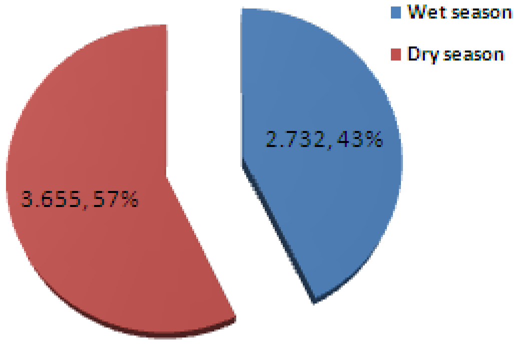

Figure 8. Mean seasonal diversity of Phytoplankton of Imo River in Etche LGA

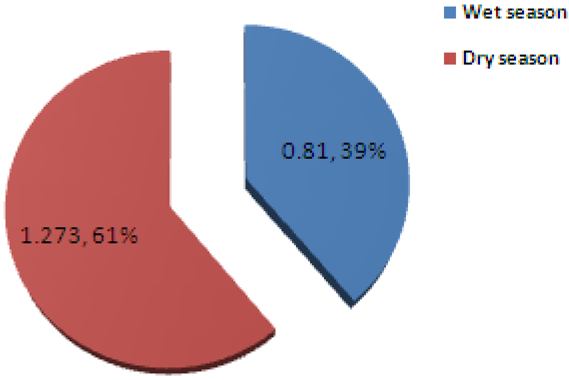

Figure 9. Mean seasonal diversity of Zooplankton of Imo River in Etche LGA

4. Discussion

The typical pattern of seasonality known for many zooplankton species in Nigerian freshwater bodies (and elsewhere), whereby abundance peaks in the dry season and low densities or total absence recorded in the wet season was also observed in the present study. Egborge (1994) attributed similar observation in Warri River to low water current velocities, more stability, concentration of nutrients, and consequent increase in biomass of food organisms during the dry season in the Niger Delta.

Two broad groups of phytoplankton- the stable and oscillating genera were observed in this study. The oscillating group varied in their presence in the seasons while the stable ones were present in both seasons. The stable genera included *Aphanizomenon, Anabaena, Oscillatoria, Microcystis* (Cyanophyceae), *Melosira, Asterionella, Nitzschia, Diatoma, Gomphonema, Pinularia* (diatoms), *Rhizosolenia, Dinobryon* (Chrysophyceae), *Closterium, Chlamydomonas, Ulothrix* (Chlorophyceae), and *Tribonema* (Xanthophyceae), while the oscillating genera whose presence depended on seasonal conditions included *Dactylococcopsis, Rivularia* (Cyanophyceae), *Achnanthes* (diatoms), *Mallomonas* (Chrysophyceae), and *Volvox, Microsterias* (Chlorophyceae). According to Kilham and Hecky (1988), the stable genera could be regarded as k-selected, because they were made up of individuals able to exploit various microhabitats offered. These genera tend to maximize utility of climatic stability prevalent in the Niger Delta region.

The observation of great seasonal influence on abundance of the green algae earlier made by Oduwole (1997) and Sowunmi (2001) in southwest Nigeria was also confirmed in the current study by increases during the dry season and decreases during the wet season. This algal biomass increase is also known to significantly out-compete less physiologically adapted species for nutrients and sunlight (Sowunmi, 2001). The lower abundance recorded during the wet season could best be attributed to further dilution of essential growth nutrients in the area (arising from increased erosion and water volumes, leading to increases in water current velocity) (Egborge, 1994). Significant dilution of essential growth nutrients for biotic communities is usually witnessed during annual episodic flooding periods at the peak of rainfall, between August and November.

Beetle larvae and crab larvae were only found in the wet season, while more fish eggs and larvae were found during the wet than dry seasons. These observations have already been attributed to the breeding habits of aquatic organisms (Zabbey et al., 2008). Reeds et al. (1967) had noted the tendencies of these organisms to move into newly inundated swamps to lay eggs and breed during flooding. Though Dejen et al. (2004) reported that silt held in suspension in turbid water (more of which was observed during the wet season) interferes with filter feeding habit of crustaceans and that this affect their reproduction success, the presence of crab larvae (crustacean) in the wet season of this study contradicts their observation. Rather, with lesser water volumes during the dry season, the contributions of suspended particulate matter by ongoing sand dredging activities in the water column may have contributed to their absence in the season, going by the observation of Dejen et al. (2004).

The current study therefore reveals significant seasonality-induced variations in abundance and diversity of plankton biotypes of the Imo River in the Niger Delta ecozone of Nigeria. The observed significant difference in plankton abundance between 2007/2008 and 2008/2009 sampling periods reflects perturbation-induced impacts on the habitats of the biotypes. The major perturbation in the water column here is in-stream sand mining, which has been on the increase in recent years.

5. Conclusion

Phytoplankton species identified were seasonally dominated by the bacillariophyceans (diatoms). The least qualitative biotypes encountered were the pyrrophyceans and xanthophyceans, and the least quantitative was the euglenophyceans. Zooplankton species encountered were dominated by the cladocerans, while beetle larvae were the least abundant biotype encountered. Though not significantly influenced by season, relatively higher mean plankton abundances and diversities were recorded in the dry season. Both phytoplankton and zooplankton taxa showed significant numerical differences between the 2007/2008 and 2008/2009 sampling periods; an observation that could be linked to water column perturbations.

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Appendix 1. List of plankton divisions and species identified in Imo River in Etche LGA (March 2007-February 2009)

PHYTOPLANKTON

Bacillariophyceae

Asterionella formosa Hassal

Achnanthes gracillina Her.

Bacillaria paradoxa Gmel.

Cyclotella kutzingiana Thwaites

C. meneghiniana Kūtz.

C. operculata (A.g.)

Cymbella afinis Kūtz.

Diatoma elongatum Agadh.

D. spp.

Fragilaria capucina Desm.

Gomphonema parvulum (Kūtz.)

Gyrosigma attenuatum (Kūtz.)

Melosira spp

M. varians C.A. Ag.

M. pusilla

Navicula cuspidate

N. dicephala (Ehr.)

N. gracilis Ehr.

Nitzschia ricta Hantsch.

N. filiformis (W. Smith)

N. closterium W. Smith

N. gracilis Hantsch

Pinularia viridis (Nitzsch)

P. divergens Kutz.

P. appendiculata Clev.

Stauroneis anceps Her.

Synedra ulna (Nitzch) Her.

Tabellaria binalis (Her.)

T. fenestrata Kūtz.

<u>Cyanophyceae</u>

Anabaena spiroides Kleb

Aphanizomenon flos-aquae (L.) Ralfs.

Dactylococcopsis acicularis Lemm.

Gloeocapsa spp

Gomphosphaeria lacustris Chod.

Lyngbya limnetica Lemm.

Microcystis aeruginosa (Kūtz.)

Oscillatoria tenuis Ag.

Phormidium spp

P. mucicola Hub-Pestalozzi et Naum

Raphidiopsis curvata Fritsch et Rich.

Rivularia planctonella Elenk.

<u>Chlorophyceae</u>

Closterium gracile Bréb.

C. parvulum Nãg

C. kuetzingii Bréb.

Cosmarium spp

C. circulare Reinsch.

Chlamydomonas spp

Microsterias thomasiana Arch.

Spirogyra spp

Ulothrix spp

Volvox globator (L.) Her

Chrysophyceae

Dinobryon divergens Imh.

Mallomonas caudate Conrad.

Rhizosolenia eriensis H.L. Smith

Euglenophyceae

Euglena gracilis Klebs.

Phacus spp

Trachelomonas lacustris Drez.

Pyrrophyceae (Dinoflagellata)

Cryptomonas erosa Ehr

Gymnodinium aeruginosum Stein.

Xanthophyceae

Tribonema vulgare Pasch.

T. utriculosum (Heering)

ZOOPLANKTON

Cladocera

Alonella rostrata (Koch)

Bosmina longirostris (O.E. Mūller)

Chydorus gibbus Lilljeborg

Daphnia hyalins (Leydig)

D. carinata Sars

Pleuroxus spp

Copepoda

Canthocamptus staphylinus (Jurine)

C. carinetus Shen et sung

Paracyclops finibriatus (Fischer)

Limnocalanus macrurus

Senecella calanoides Sar

Other crustaceans

Crab larvae

Pisces

Fish eggs

Fish larvae

Insecta

Beetle larvae

Rotifera

Colurella spp

Keratella valga Ehr

Branchionus forficula Wierzejski

Rotifer spp

Protozoa

Arcella arenaria Greff.

Didinium bolbianii (Fabre-Domergue)

Peridinium bipes Stein